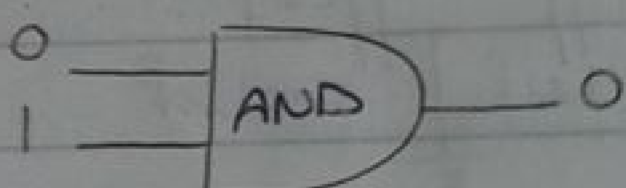
Section (5):

Ch 3: Multivibrators

Logic gates OR, AND

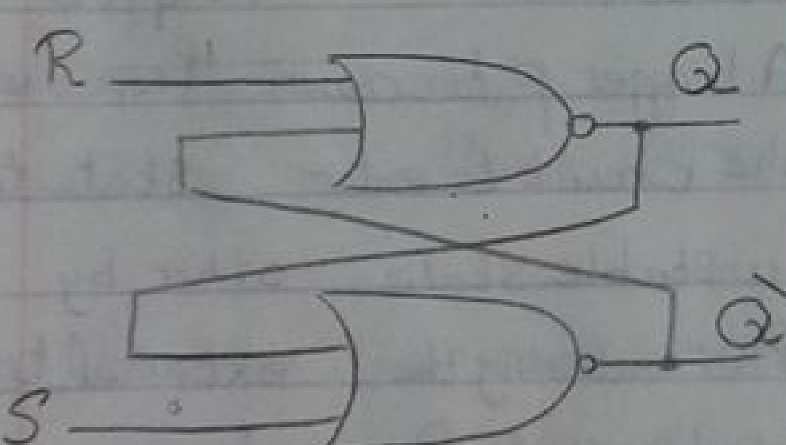
- There are two types of Logic circuits: Combinational logic circuits and Sequential logic circuits.

Combinational Logic circuits	Sequential Logic circuits
The output depends only on the current inputs.	The output depends on the current inputs and also on the past sequence of inputs
	Sequential Logic is Combinational Logic with memory.
	It is divided into Synchronous and asynchronous types.

Asynchronous Seq. Logic

- The state of the device can change at any time in response to changing inputs.
- For example, Latches
  - * S-R Latch
  - * D- Latch
- S-R Latch

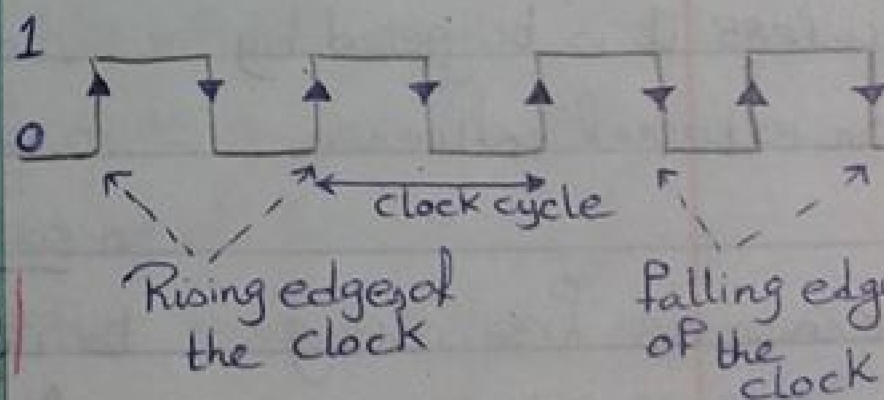
R



	S	R	Q	Q̀
بيظهر هنا ال Seq.	0	0	lastQ	lastQ̀
Reset ←	0	1	0	1
Set ←	1	0	1	0
	1	1	0	0

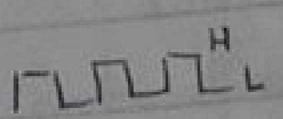
Synchronous Seq. Logic

- The state of the device changes only at discrete times in response to a clock signal.
- Flip-Flops
  - * S-R flip-flop
  - * D Flip-flop
- A clock signal is periodic square wave that indefinitely switches values from 0 to 1 and from 1 to 0 at fixed intervals



- The state transition in such circuits occur when only the clock value is 0 or 1 or at the rising or falling edges depending on the type of memory.

- Clock Signals are Produced by a single Pulse generator Circuit such as a Multivibrator.

- Multivibrator is charachterized by two amplyfing devices (transistors for example) cross-coupled by resistors or Capacitors
- 
, has two States "High" and "Low"

Multi Vibrator

Astable

- the circuit is not Stable in either states - Continually Switches from one State to another
- Stable circuit means it maintains its State unless it is triggered by an external influence
- Known as "free-running" multivibrator because it alternates between two different output voltage levels during the time it is on.

MonoStable

- One of the States is Stable but other is unstable
- A trigger Pulse causes the circuit to enter the unstable State
- after entering the unstable State for a set time it will return to its Stable state.
- useful in creating a timing Period of fixed duration in response to Some external event.
- Know as "One Shot"

BiStable

- Stable in either St
- flipped from one State to other by external trig
- Known as "flipflop"
- used to Store one b of info

- Multivibrator is "an electronic circuit used to implement two-state systems such as oscillators, timers & F/Fps".

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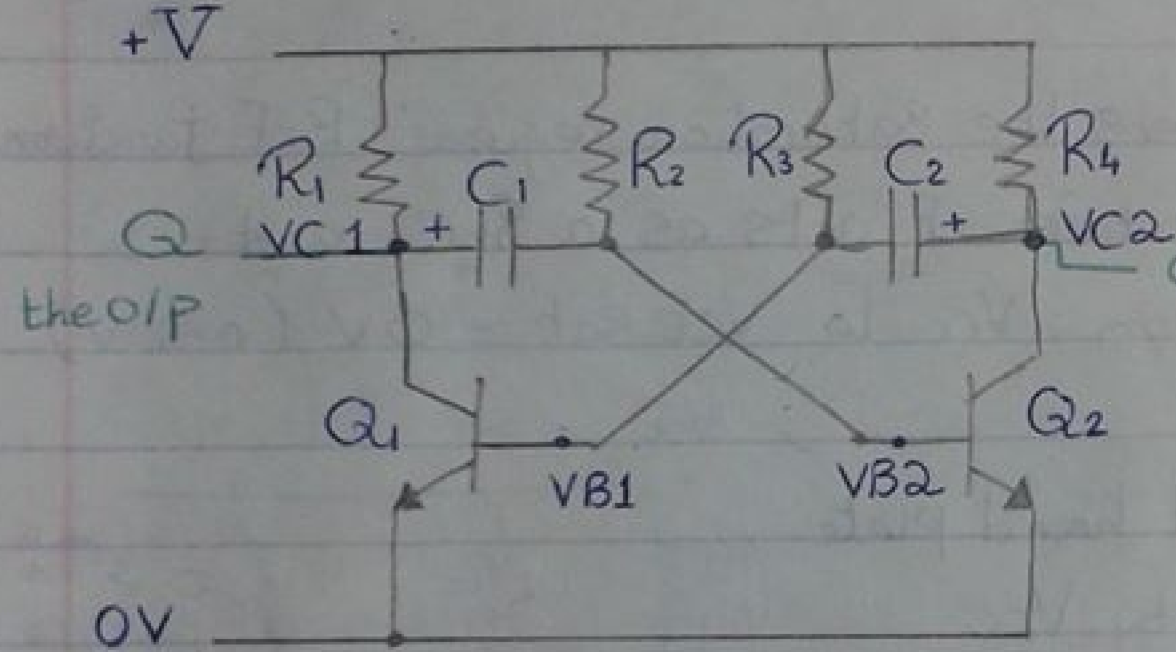
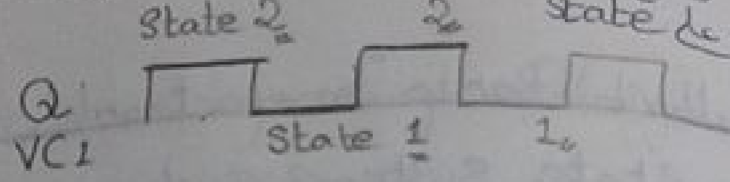
1 Astable Multivibrator



Basic BJT astable multivibrator

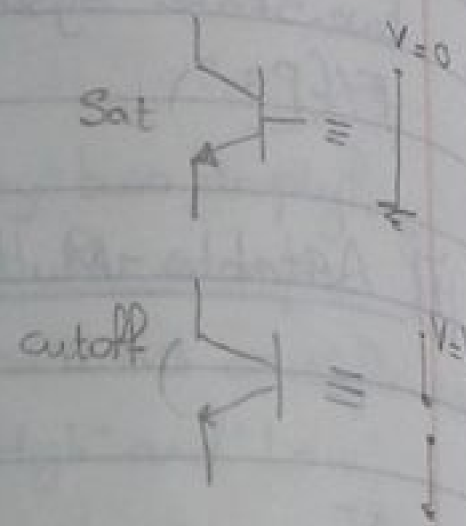
- It has two outputs but No inputs.
- drawn in a symmetric form as a cross-coupled Pair.
- It is a regenerative circuit consisting of two amplifying stages connected in a positive feedback loop by two capacitive-resistive coupling networks.
- The amplifying elements may be BJT, FET, vaccum tubes or OP-amp.

واضح من الخرج ان الـ Circuit بتتغير من ١ لـ ٢ والعكس ولا تثبت على state

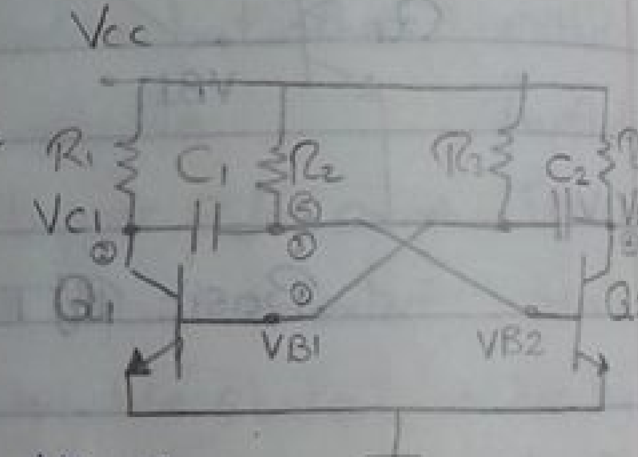


Operation :

State 1 (Q_1 on , Q_2 off)



- The circuit enters this state when C_2 charges to the point where V_{B1} reaches V_{on}.
- Then Q_1 enters the saturation region (B-E junction is forward) where it acts as a S.C. and pulls V_{C1} from V_{CC} to $V_{CE\,sat} \simeq 0V$ (0.2V)



- When the left-hand plate of C_1 drops by V_{CC} this will cause an equal and instantenous drop on the right-hand plate which will be $1V - V_{CC}$ was V_{B2} when it was On at State 2.

- Q_2 turns off due to the negative voltage on

its bas…

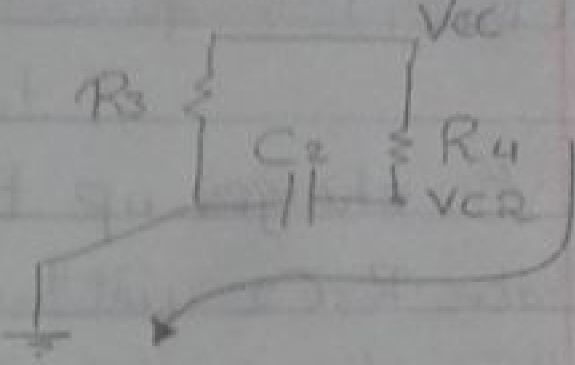
- V_{C2} ch… to V_C… depend… R_4C_2)…
- V_{B2} c… R_2 to… (chang… depend…

* R_2C_1… the ti… the c… State… becaus… V_{B2} =… State…

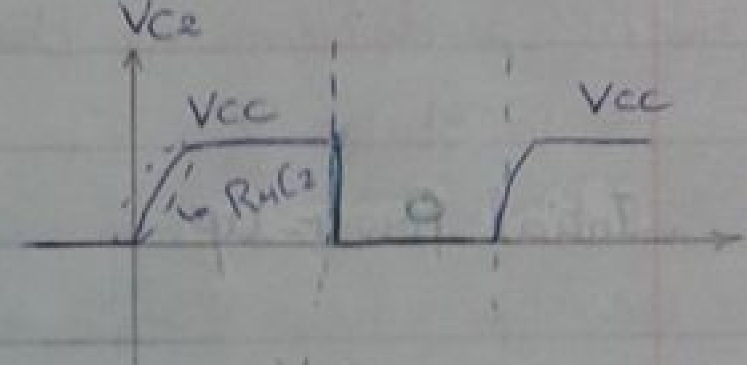
- When… Pulle…
- the ri… by V…

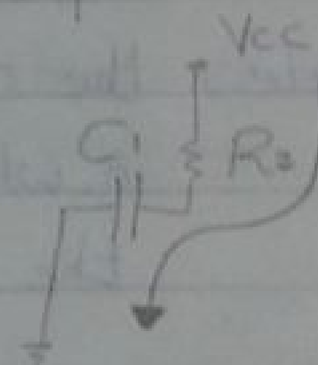
its base.

- V_{C2} charges up through R_4 to V_{CC} (charging time depend on the time constant $R_4 C_2$).



- V_{B2} charges up through R_2 towards V_{CC} (Changing time depend on $R_2 C_1$)





* R_2C_1 determines the time in which the circuit stays in State $\underline{\underline{1}}$
because the circuit will be in State $\underline{\underline{2}}$ when $V_{B2} = V_{ON}$.

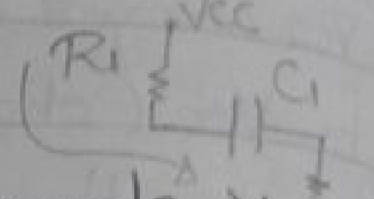
State $\underline{\underline{2}}$ (Q_1 off , Q_2 on)

- When V_{B2} reaches V_{ON}, Q_2 turns on and V_{C2} is Pulled to 0 V.

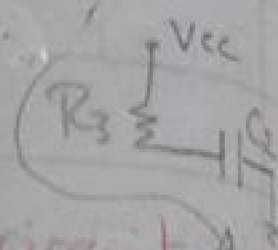
- the right hand Plate of C_2 which is V_{B1} will drop by V_{CC} and it will be $V_{ON} - V_{CC}$.

as Q_1 was On at State $\underline{\underline{1}}$

. Q_1 turns off due to the negative voltage on its base and V_{C1} charges up to V_{CC} by rate (R_1C_1).



. V_{B1} charges up through R_3 towards V_{CC} at rate R_3C_2 until V_{B1} reaches **V_{ON}** then the circuit enters state $\frac{1}{2}$ again.

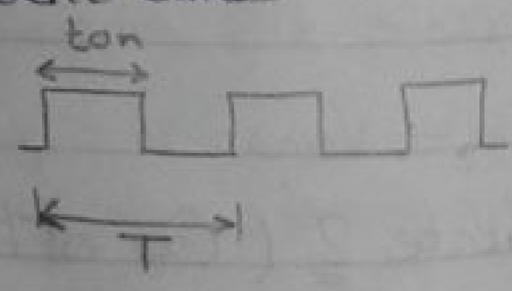


* R_3C_2 determines the time in which the circuit is in state $\underline{2}$.

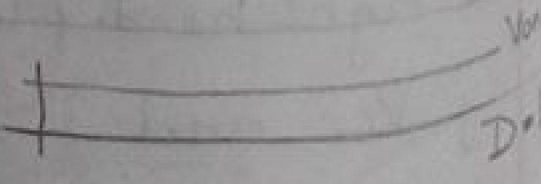
. Duty Cycle: the ratio between the time duration in which the signal is high to the total period of the signal.

$$D = \frac{t_{on}}{T} * 100\ \%$$

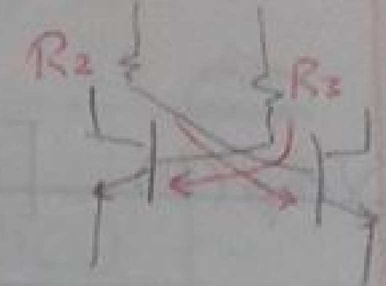
$T \rightarrow$ Periodic time



$D = 50\ \%$



- Intial Power-up:

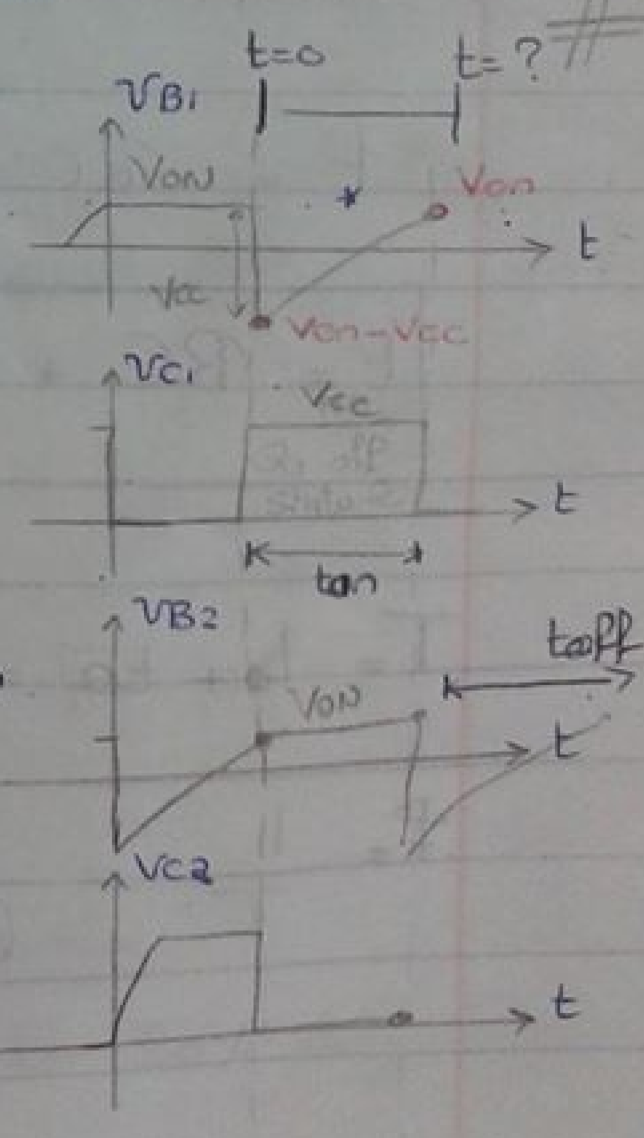


you may ask yourself how will the operation start intially when there is no input ?!

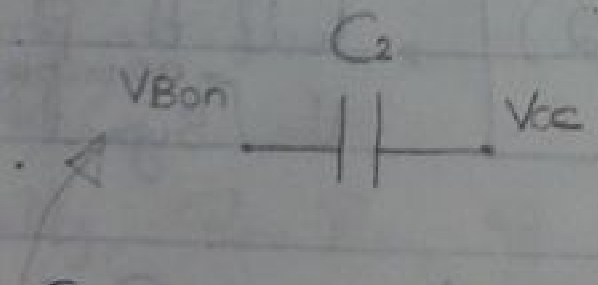
- Parasitic capacitors between B and E of Q_1 and Q_2 are charged up towards V_{cc} through R_2 and R_3. Boths V_{B1} and V_{B2} rise.

- Due to fabrication asymmetries between the two transistors One of them will switch on first and the circuit will be Put into one of the above states.

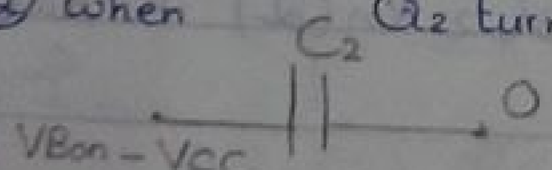
- Frequency of oscillation:



at State ① before Q_2 turns on.



at state ② when Q_2 turns on



* the capacitor should charge back to V_{on}.

$$V_{cap}(t) = \left[(V_{cap\,initi} - V_{charging}) \times e^{-t/RC} \right] + V_{ch}$$

$$V_{on} = \left[(V_{on} - V_{cc}) - V_{cc} \right] e^{-t/R_3C_2} + V_{cc}$$

عاوز أعرف t تساوي كام عند $V_{B1} = V_{on}$ بعوض بدأنا بـ $t=0$ عند $V_{on} - V_{cc}$

$$\ln\left(\frac{V_{on} - V_{cc}}{V_{on} - 2V_{cc}}\right) = -t/R_3C_2$$

$$t = -R_3C_2 * \ln\left(\frac{V_{on} - V_{cc}}{V_{on} - 2V_{cc}}\right)$$

$\because V_{on} \ll V_{cc}$

$$t = -R_3C_2 * \ln\left(\frac{1}{2}\right)$$

$$\boxed{t_{on} = R_3C_2 * \ln(2)} \rightarrow$$ half the Period of the astable multivib signal

$$T = t_{on} + t_{off} = R_3C_2 \ln(2) + R_2C_1 \ln(2)$$

$$f = \frac{1}{T} = \frac{1}{\ln(2)\left[R_3C_2 + R_2C_1\right]}$$

arging

$$\boxed{f \approx \frac{1}{0.693 \cdot (R_2C_1 + R_3C_2)}}$$

Freq. of oscillation of astable multivibrato

- Duty cycle: the ratio between the time duration in which the o/p is high to the total Period of Signal.

$$D = \frac{t_{on}}{T} * 100\%$$

if $t_{on} = \frac{1}{2} T$

$D = \frac{1}{2} = 50\%$

. For the o/p signal to have a duty cycle of 50% the charging time of C_1 must equal charging time of C_2.

(i.e. $R_2C_1 = R_3C_2$)

So Practically, $R_2 = R_3$, $R_1 = R_4$, $C_1 = C_2$

Hence, $f \approx \frac{1}{2\ln(2) \cdot R_3C_2}$

$$\boxed{f \simeq \frac{0.72}{RC}} \rightarrow \text{for 50\% duty cycle}$$

Section (6)

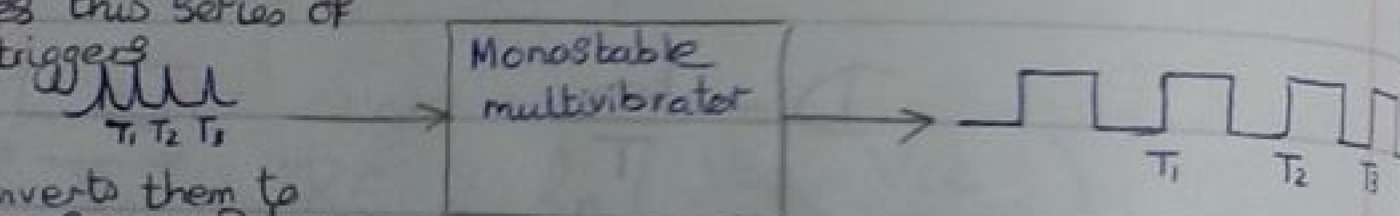
2 Monostable Multivibrator

- Is a square - or rectangular - wave generator with just one stable condition.

- Sometimes called a One-shot Multivibrator.

- Basically used for pulse stretching.

* it takes this series of input triggers



and converts them to uniform square pulses

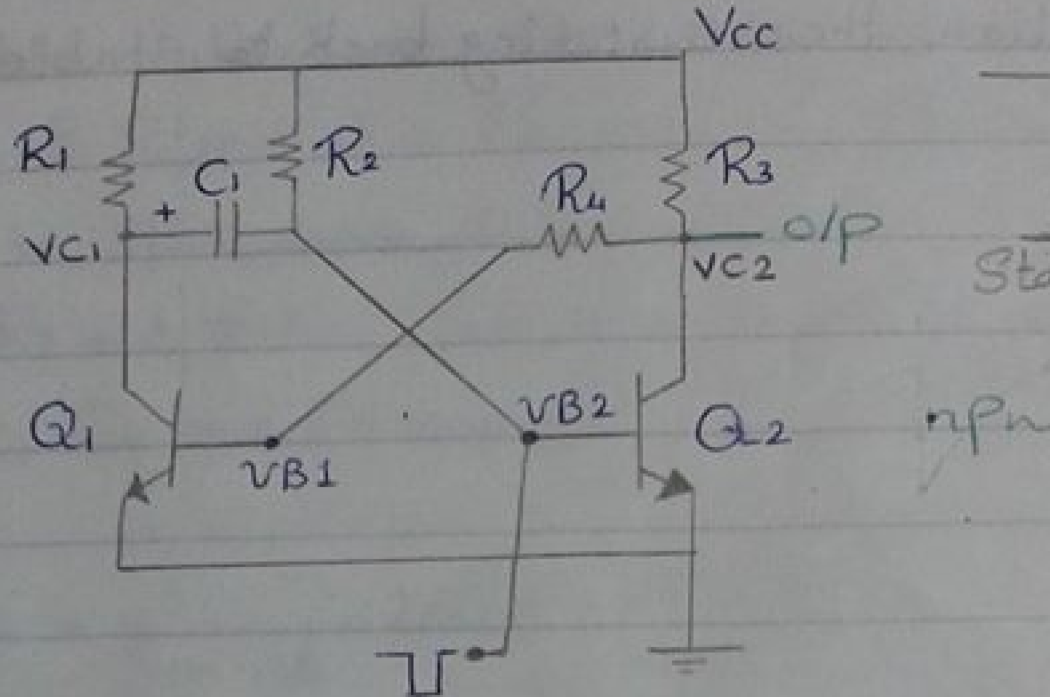
- used in Computer logic systems and communication navigation equipment.

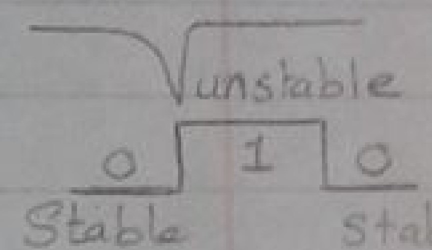
- The o/p is on Q_2 in contrast to the astable circuit, it has a perfect square waveform since the output is not loaded by a capacitor.

- One o/p

oneshot because one trigger generates one gate

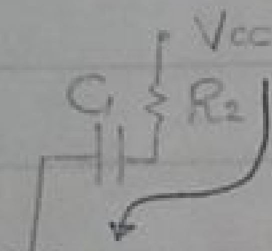
- Operation :





Basic BJT MonoStable Multivibrator

- The circuit is Stable at State $\underline{\underline{2}}$ (Q_1 off, Q_2 on)
- When VB2 is triggered by Zero or negative signal, Q_2 becomes off.
- VC2 rises to Vcc, VB_1 increases and Q_1 becomes On → thus the circuit is now in State $\underline{\underline{1}}$



- V_{C1} Pulled down to 0V.
- When the external signal goes high
- VB2 will charge to Vcc and it will reach to Von hence, entering State $\underline{\underline{2}}$ after a time duration $t = Ln(2) R_2 C_1$.
- The circuit remains at State(2) "the Stable State"

until a trigger event changes that, the circuit then enters the unstable state for a certain duration then switching back to stable state.

Example (1).

t_1 on t_2 off

An astable multivibrator circuit is required to produce a series of pulses at a frequency of 500 Hz with a mark-to-space ratio 1:5.
If $R_3 = R_2 = 100\ k\Omega$. Calculate the values of the capacitors, C_1 and C_2 required.

$$T = \frac{1}{f} = \frac{1}{500\ Hz} = 2 \times 10^{-3}\ s.$$

1 5 t_{on} t_{off} T

$$T = t_{on} + t_{off}$$

$$t_{on} = \frac{1}{6} T = 3.33 \times 10^{-4}\ sec.$$

$$t_{off} = \frac{5}{6} T = 1.66 \times 10^{-3}\ sec.$$

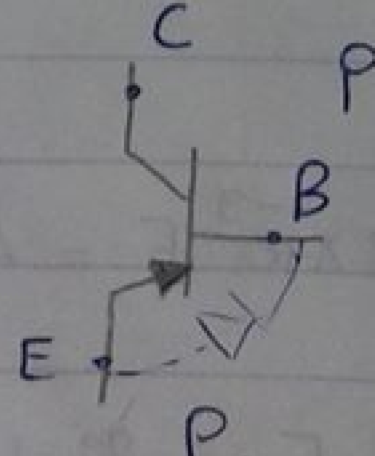
$$t_{on} = Ln(2) . R_3 C_2$$

$$\therefore C_2 = \frac{1.66 \times 10^{-3}}{0.69 \times 100\ k\Omega} = 4.83 \times 10^{-9}\ F = 4.83\ nF.$$

$$C_1 = \frac{3.33 \times 10^{-4}}{0.69 \times 100\ k\Omega} = 2.41 \times 10^{-8}\ F = 24.1\ nF.$$

3 Bistable Multivibrator

- have two Stable States.
- Trigger is needed to change the circuit from one state to the other state and then another trigger is needed to return the circuit to the first state.
- The trigger doesn't have to be of fixed frequency
- Both Capacitive-resistive networks are replaced by resisitive networks.
- Note:

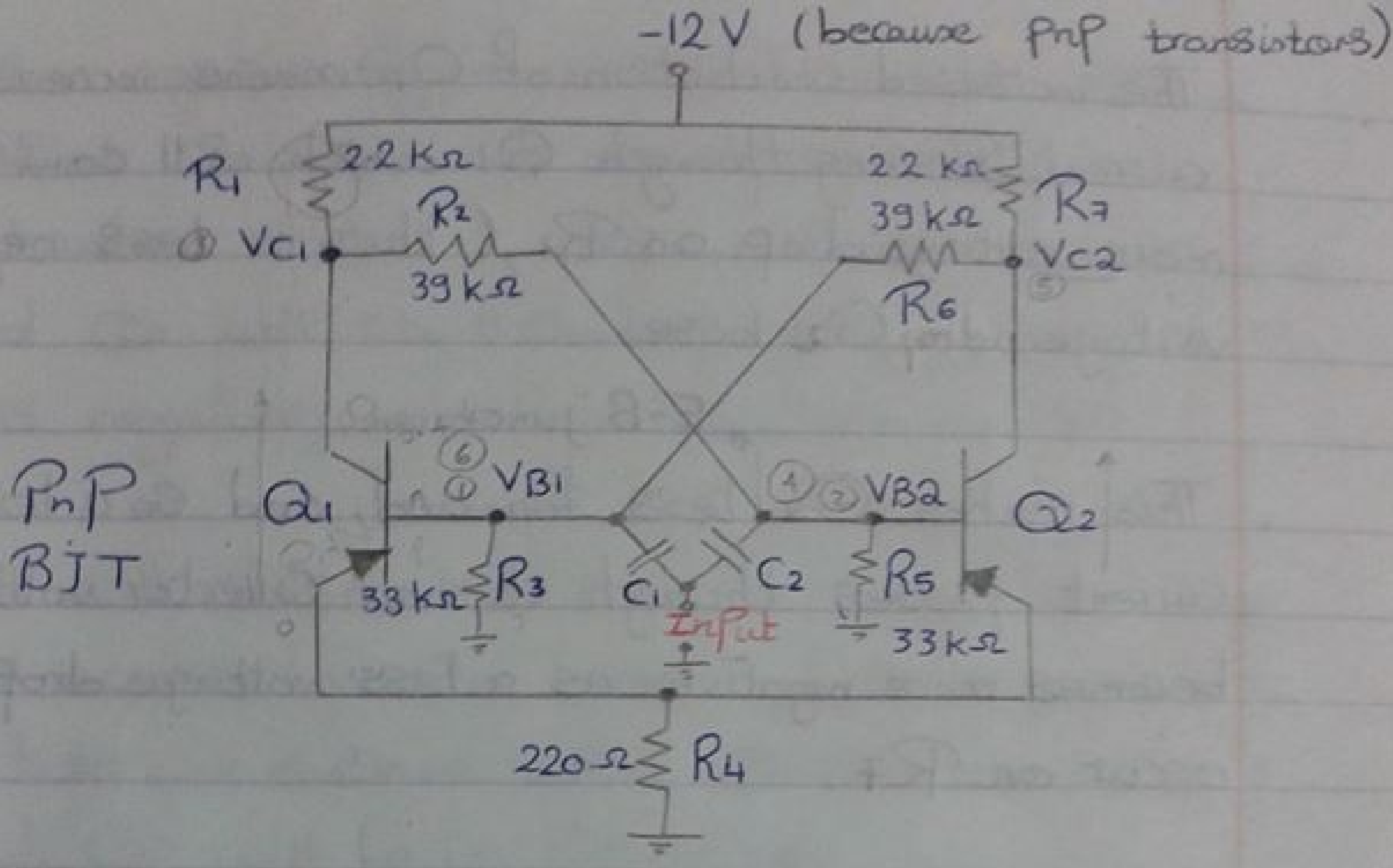


$\rightarrow$ to be on

$V_E \geqslant V_B + V_{on}$

if $V_E = 0 \rightarrow V_B \leqslant -V_{on}$

$V_B \leqslant -0.7$

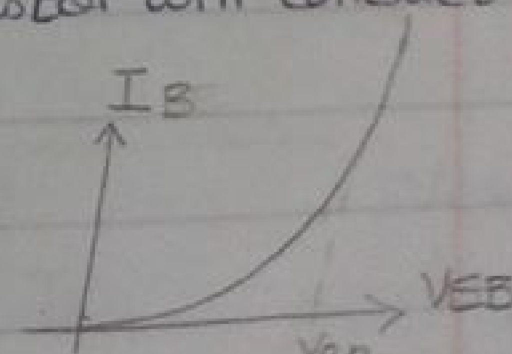


- **Operation:-**

- When Power is first applied, the voltage divider networks (R_1, R_2, R_5 for Q_2 and R_7, R_6, R_3 for Q_1) places negative voltage on the bases of Q_1 & Q_2.

- Both transistors start to conduct.

- Due to Slight difference between the two circuits (مثل سماحية المقاومات tolerance), one transistor will conduct more than the other.



- Assume Q_1 Conducts more than Q_2

-

- The increased Conduction of Q_1 means increased current Passing through Q_1 which will cause more voltage drop on R_1, thus a less negative voltage on Q_2 base.

- This makes Q_2 E-B junction less forward and so a less current passes through it and Collector voltage becomes more negative as a less voltage drop will occur on R_7.

- The more negative voltage of V_{C2} is coupled to V_{B1} through the voltage divider network So, Q_1 will Conduct even more heavily.

يعني الـ Tr يدخل بالتدريج في الـ Sat. أو الـ cutoff

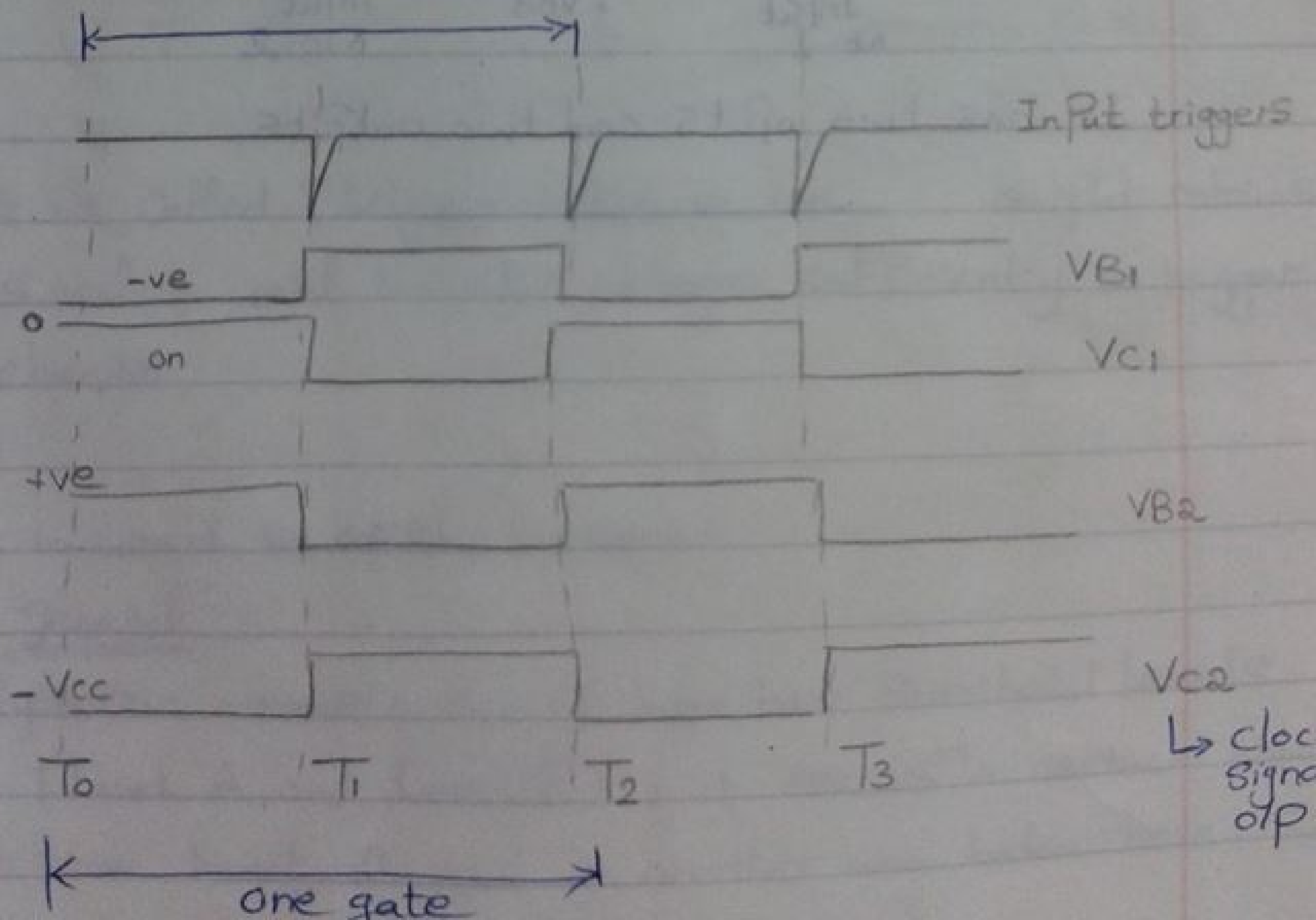
- This is called regenerative action that will continue until Q_2 is cutoff and Q_1 is saturated.

- The circuit is in a stable state and remains there until trigger is applied to switch the state.

- When negative trigger is applied now, it will not affect Q_1 as it is already conducting and in saturation but V_{B2} will be more negative and Q_2 will start conducting and V_{C2} will be less negative which is the same as V_{B1}.

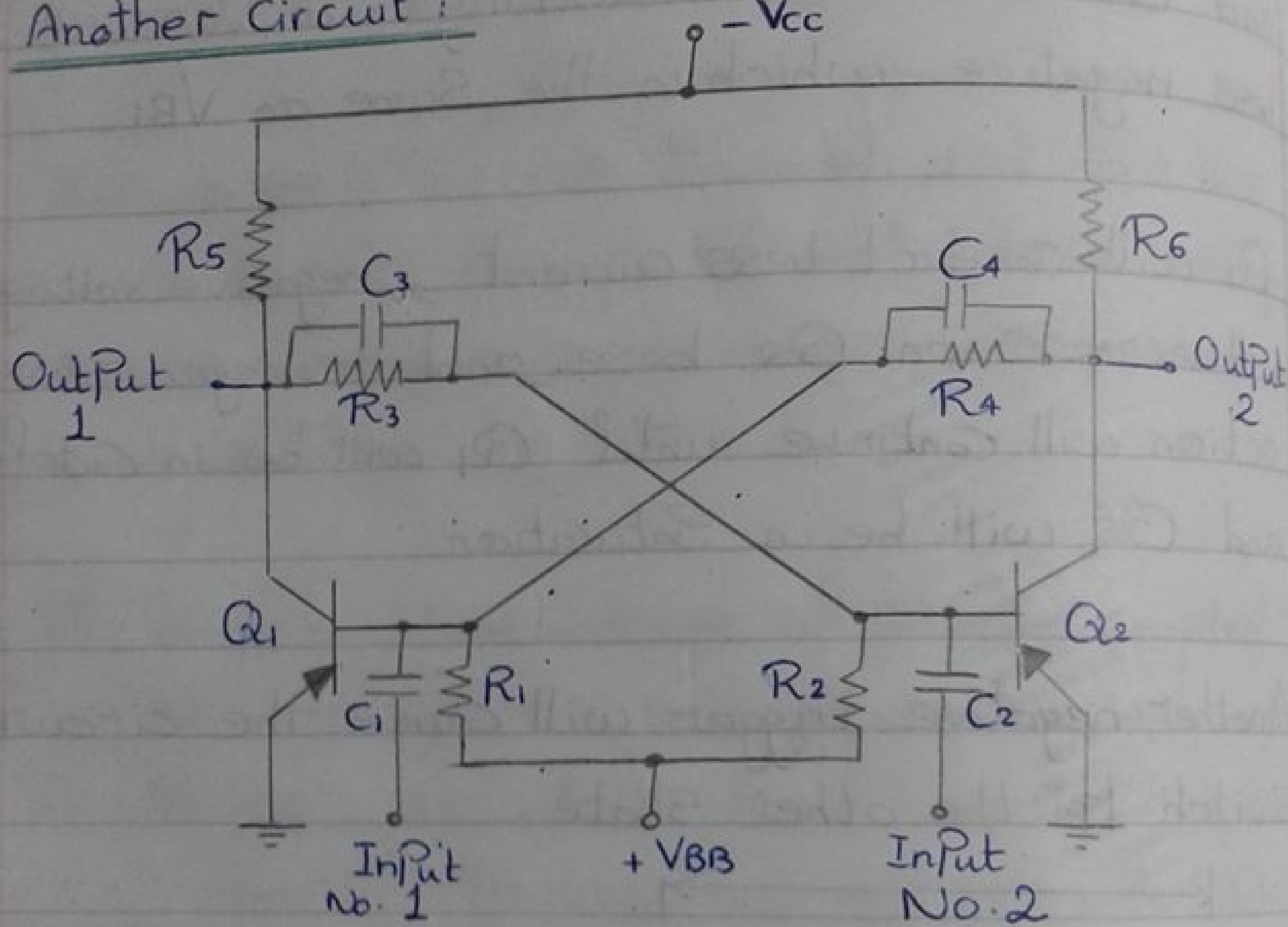
- Q_1 will conduct less current, negative voltage will increase on Q_2 base and the regenerative action will continue until Q_1 will be in cutoff and Q_2 will be in saturation.

- Another negative trigger will cause the circuit to switch to the other state.



- f/fs used as Counters, shift-registers clock Pulse generators and in memory circuits

- Another Circuit:

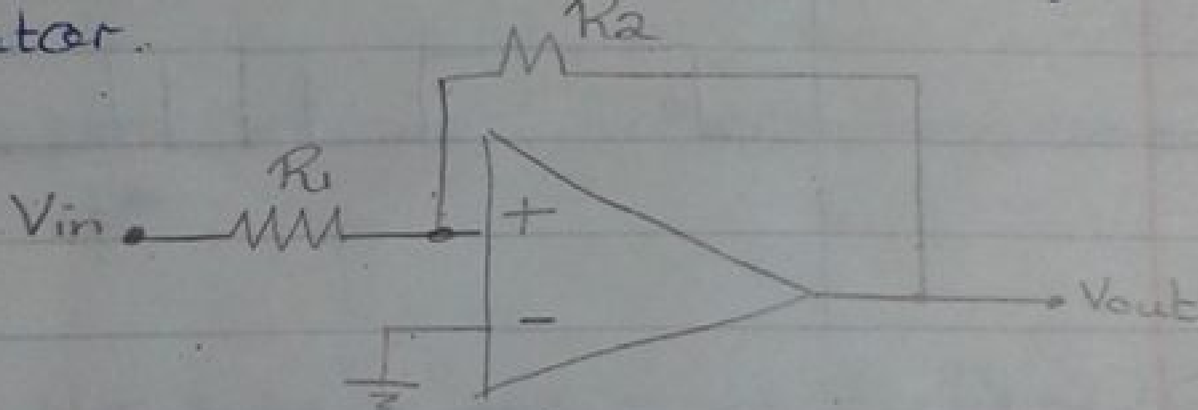


- It has two inputs and two outputs.

Schmitt Trigger

- A decision-making circuit used to convert a slowly varying analoge signal into one of two possible binary States depending on whether the analogue voltage is above or below threshold values.

- It is a Comparator circuit with hystersis implemented by applying positive feedback to the non-inverting i/p of a Comparator.



- It is called "trigger" because the output retains its value until the input changes sufficiently to trigger a change.

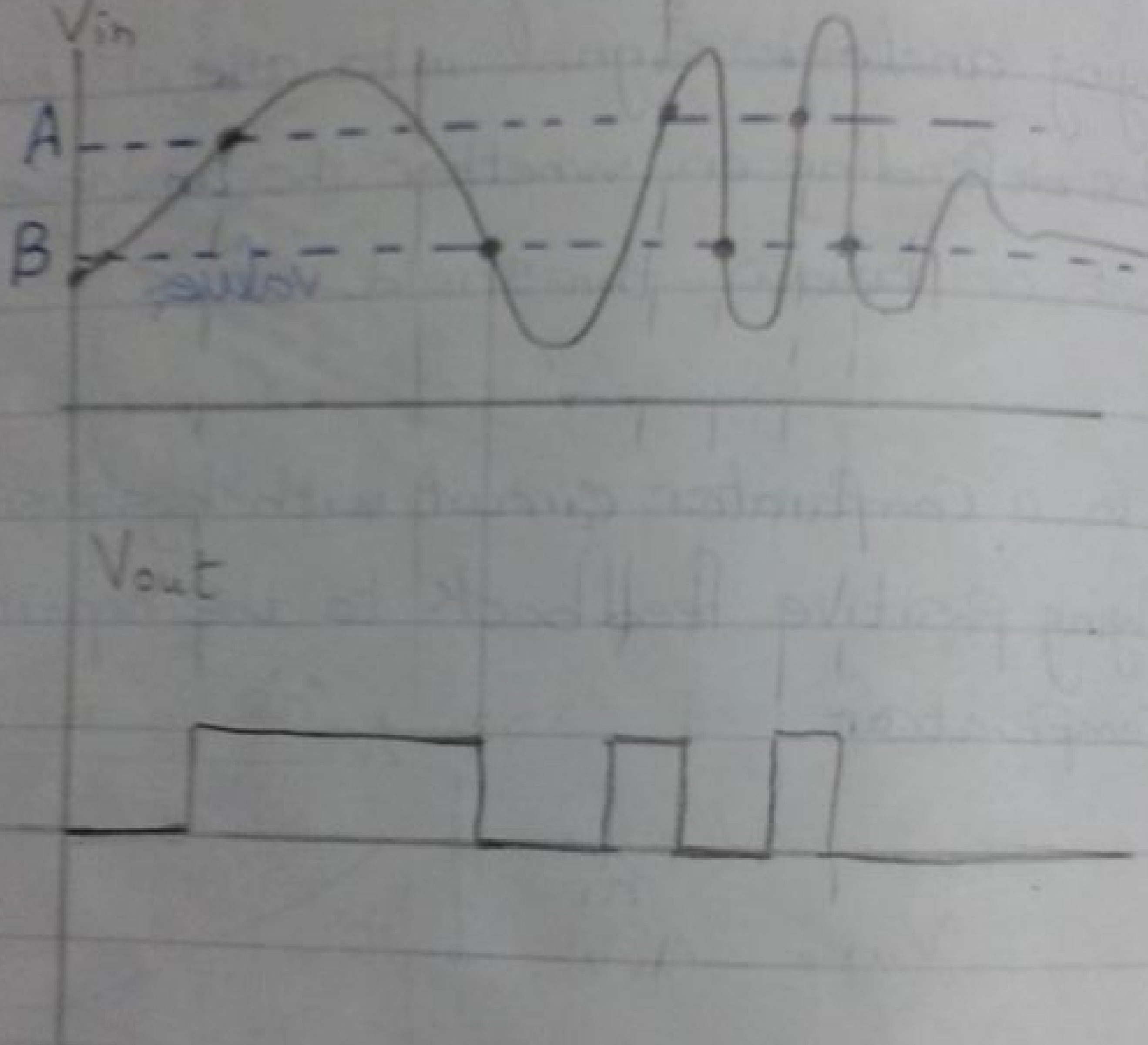
- It is used to apply hystersis

<u>In general</u>

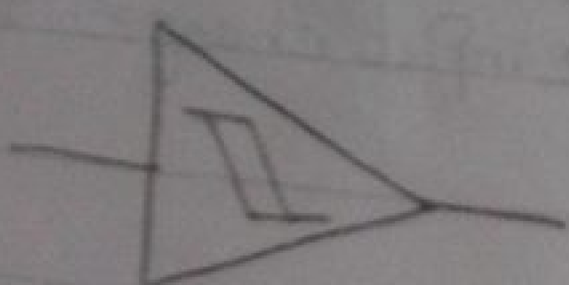
- Hystersis means (a circuit have two threshold levels (Level A and Level B), it reacts in a certain way above Level A and in another way below Level B but in between it doesn't react.

Here, if V_{in} > Level A $\longrightarrow$ o/p is H

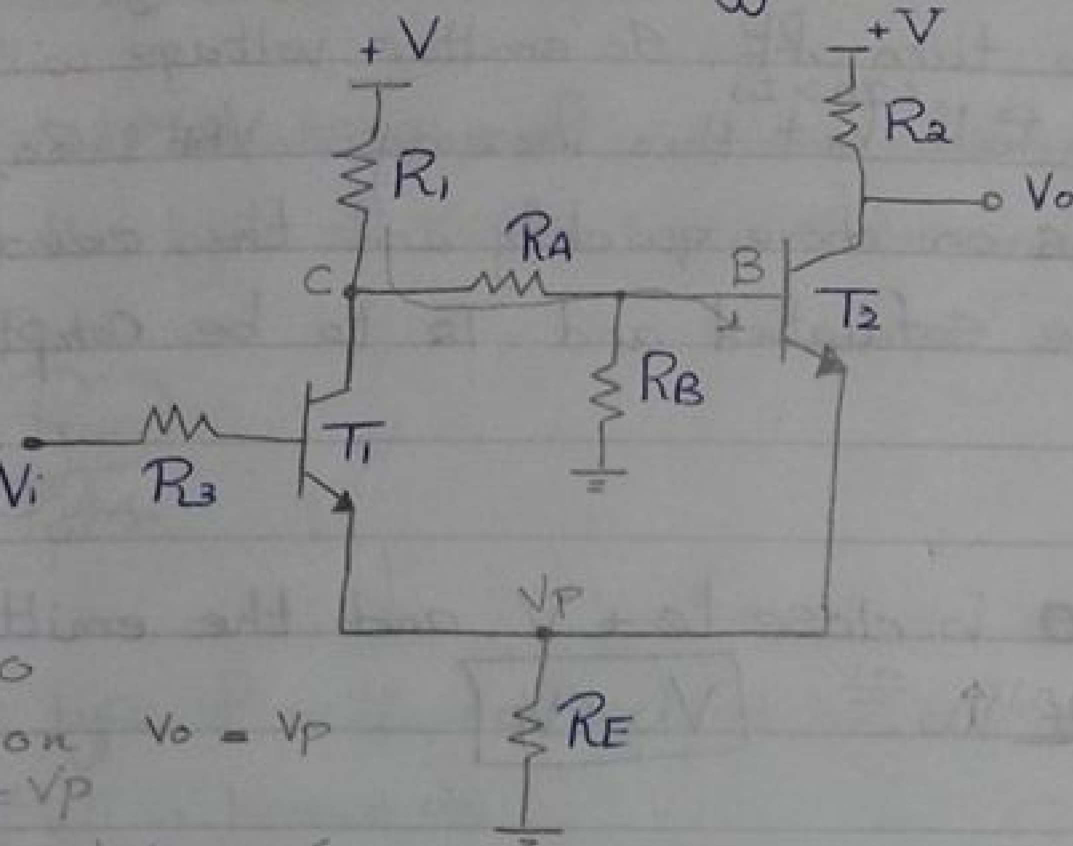
V_{in} < Level B $\longrightarrow$ o/p is L



Schmitt trigger symbol



- Two-transistor Schmitt trigger:



① $V_i = 0$
② T_2 on $V_o = V_p$
③ $V_E = V_p$
④ If $V_i > V_p + 0.6$
⑤ T_2 off $V_o \approx +V$ $V_E = V_N$

1. If V_i is close to Zero, T_1 has no base current So it is off.

- T_2 draws the base current through R_1, R_A and R_B So it is On. (Saturated) and acts as a S.C.

- V_o sits at the mid-point of R_2, R_E potential divider somewhere between $+V$ and $\perp$. (V_P).

2. If V_i starts to increase and emitter voltage is held at a fixed value by current through T_2.

- When V_i increases about 0.6 above this value (V_P)

- T_1 starts to conduct as it does, [illegible] (not s.c.)

- The base current of T_2 starts decreasing and T_2 starts to turn off. So emitter voltage will start to fall ($I_2 > I_1$) but this increases V_{BE1} so, T_1 turns on more quickly and this causes T_1 to be saturated and T_2 to be completely off.

- Now, V_0 is close to $+V$. and the emitter voltage is V_N. $\boxed{V_N < V_P}$

[3] - If V_i starts to fall back towards zero. V_i has fallen to about 0.6 V above this value (call it V_N).

- T_1 will start to turn off so T_2 will begin to turn on so V_E will increase and this will let T_1 turn off more quickly returning V_0 to V_P.

- The difference between the two thresholds is called hystersis.

- Mu

1. Th
b
ou
(a)
(b)

2. T
ou
(a
(b
(c

3. T
o
(a)
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4.
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(
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7- What is the type of the multivibrator shown in the previous figure and what is the idea of its operation?